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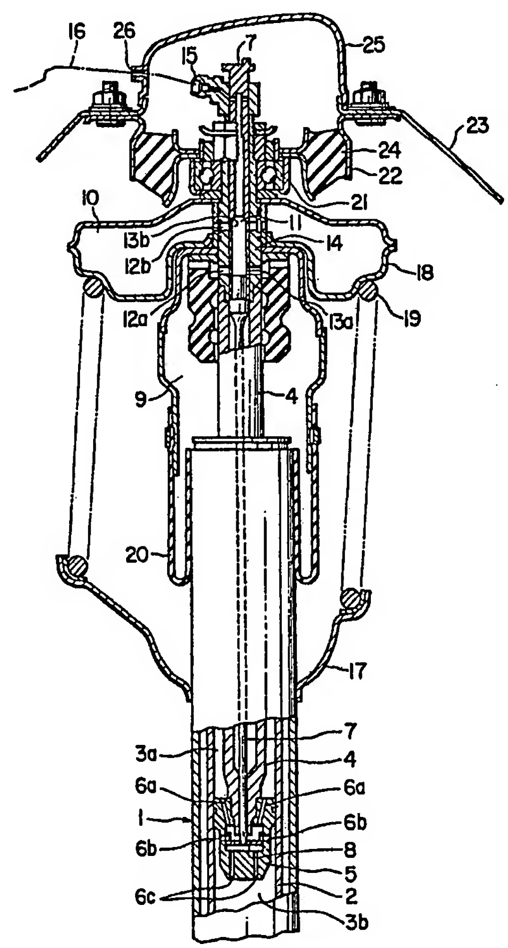
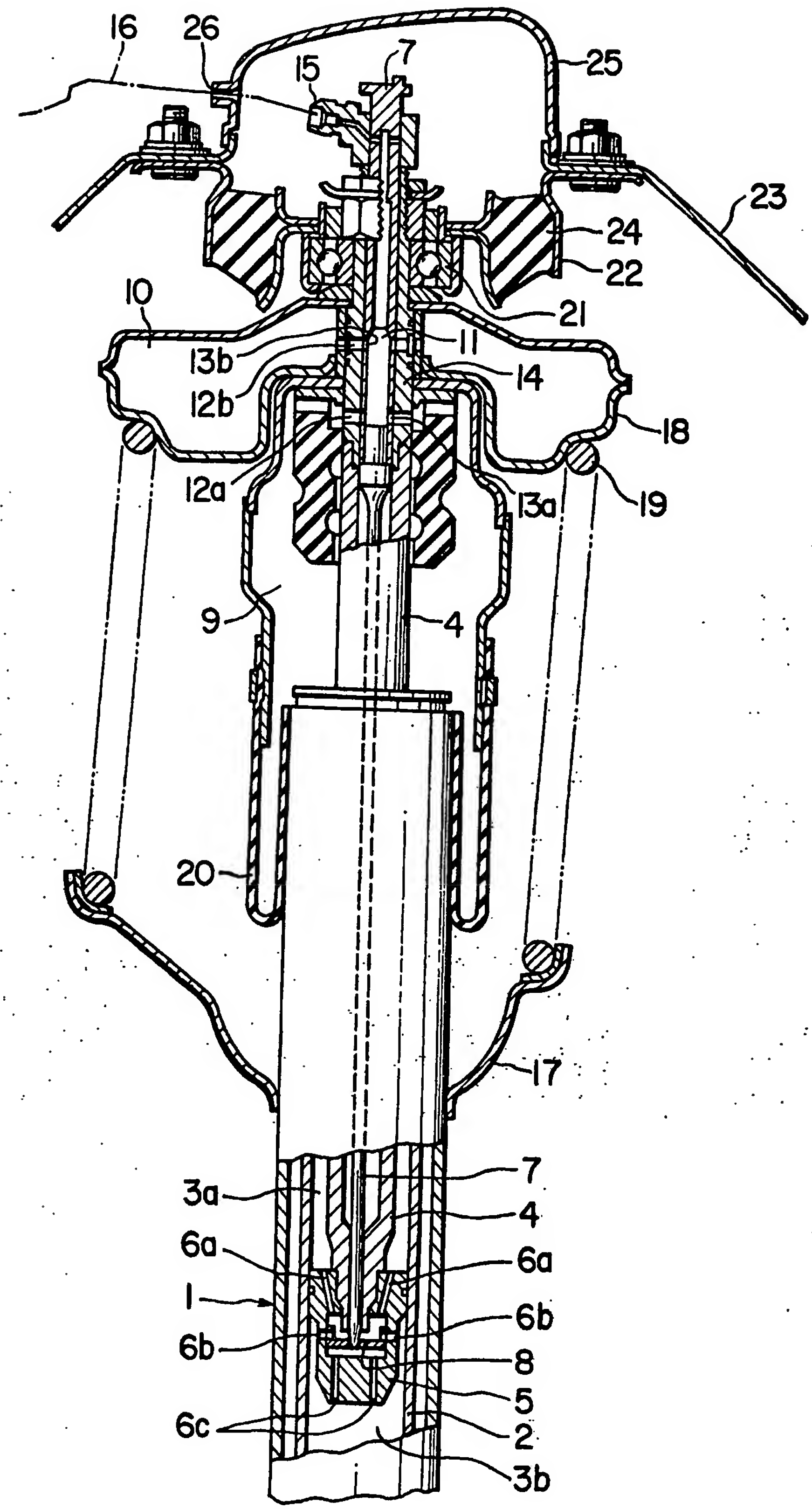
(54) A suspension unit with telescopic damper and adjustable rate air spring

(57) In a suspension unit for automobiles and other vehicles, an auxiliary air-spring chamber 10 is provided above a main air-spring chamber 9 in such a manner as to enclose a piston rod 4 of a shock absorber and the spring force of the suspension can be adjusted. An air passage 11 to connect the two air-spring chambers 9, 10 is provided in the piston rod 4. The piston rod 4 and a control rod 7 extending inside the piston rod make up a switch valve that controls the connection and disconnection of the main and auxiliary air chambers via the passage 11 to alter the spring rate. The damping force of the shock absorber can also be adjusted by means of the same control rod, the damping being greater when the switch valve is closed i.e. the auxiliary air spring chamber is isolated. The control rod may be rotatable, or linearly movable. The air passage 11 is also connected via a coupling, with a line 16 extending to a valve via which the passage 11 can be connected with a source of air under pressure or with the atmosphere for levelling the unit. The upper end of the suspension unit is enclosed by a cover 25 to reduce the propagation of the noise resulting from the inflow and outflow of air through the air passage 11.

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SPECIFICATION

A suspension unit for a vehicle and a vehicle incorporating the same

This invention relates to a suspension unit for a vehicle and to a vehicle incorporating the same.

Suspension systems for vehicles are known which incorporate air-spring-assisted vehicle-height adjusting mechanisms.

With some known suspension systems, however, it has been impossible to change the spring constant freely in accordance with varying running conditions while maintaining a given car height. Thus, if the spring constant is set at low level, the vehicle body may roll and/or pitch heavily, with a resulting impairment of steering stability, when the vehicle is travelling over an uneven surface. If, on the other hand, the spring constant is set at a higher level to secure steering stability, riding comfort is reduced.

A modified type of suspension systems is also known which comprises, for each wheel, an auxiliary air-spring chamber of a fixed capacity connected to a main air-spring chamber associated with a suspension strut for the respective wheel, and a valve, herein referred to as a switch valve, interposed between the two air-spring chambers, which can be opened to connect the chambers, or closed to cut the main chamber off from the auxiliary chamber. When this valve is closed, a relatively large spring force is obtained as only the air contained in the main air-spring chamber is effective. When the valve is opened, a relatively small spring force is obtained by use of the total volume of the air contained in the main and auxiliary air-spring chambers.

This modified type of system also has not been without shortcomings. Because the auxiliary air-spring chamber is positioned away from the respective suspension strut, it is necessary to provide space in the vehicle to accommodate the auxiliary air-spring chamber itself, a passage interconnecting the two air-spring chambers, and the switch valve. It is also necessary to provide some means to protect the interconnecting passage and switch valve.

It is an object of the present invention to provide an improved suspension unit incorporating an air-spring.

According to one aspect of the invention there is provided a suspension unit for a vehicle including a cylinder, a piston slidable in the cylinder and dividing the space within the cylinder into two chambers, a piston rod extending from the piston axially through one of said chambers and passing sealingly through one end of the cylinder to project therefrom, the suspension unit including a main air-spring chamber of variable volume, and an auxiliary air-spring chamber, disposed around said piston and cylinder at respective axial positions therealong, said piston rod having a longitudinal central passage therein which receives a control rod extending from the piston rod at one end whereby the control rod can be moved relative to the piston rod, said piston rod forming, with said control rod, a control valve which in one position of the control rod relative to the piston rod provides communication between said main and auxiliary air-spring chambers via ports formed through the wall of the piston rod and via said longitudinal central passage, and which control valve, in another position of the control rod relative to the piston, roo cuts off such communication.

According to another aspect of the invention, there is provided a vehicle having a body, wheels and a suspension system incorporating a suspension unit according to the first-noted aspect of the invention extending between the vehicle body and a wheel-supporting member, and means for effecting control movement of the control rod relative to the piston rod.

An embodiment of the invention is described below, by way of example, with reference to the sole figure of the accompanying drawing which is a view in vertical cross-section showing part of a vehicle suspension system embodying the invention.

The drawing shows only the region of the body 23 of a vehicle, in this case a motor car, to which the upper end of a suspension unit (shown only partially) for one wheel (not shown) is attached. It will be understood that the vehicle in question has similar suspension units (not shown) associated with the other wheels thereof (not shown).

The suspension system illustrated is of the strut type. Reference numeral 1 designates a shock absorber of variable damping capacity, and which comprises a cylinder 2 connected at its lower end (not shown) to the wheel axle or other wheel support (not shown). A piston 5 fitted in the cylinder 2 divides the internal space thereof into two hydraulic chambers 3*a* and 3*b*. Passages 6*a*, 6*b* and 6*c* provided in the piston 5 connect the two hydraulic chambers 3*a* and 3*b*, and a piston rod 4 extends upwardly from the piston 5 to pass sealingly through the upper end of cylinder 2 and at its upper end passes through a mounting bearing 21, to which it is secured, the bearing 21 being in turn held in a rubber mount 24 fixed in a bracket 22 secured to the vehicle body 23. The piston rod 4 has an axial longitudinal passage therethrough, and a control rod 7 extends axially within the piston rod 4 and projects from the upper end of the piston rod, the control rod being capable of rotating with respect to the piston rod. A control valve 8 is attached to the lower end of the control rod 7, within a cavity formed within the piston and is operable to change the effective cross-sectional area of the communication provided through the piston between chambers 3*a* and 3*b* via the passages 6*a*, 6*b* and 6*c* and said cavity.

More specifically passages 6*a* extend from chamber 3*a* to the cavity in piston 5 and passages 6*a* and 6*c* extend from this cavity to the chamber 3*b*. The cavity is generally cylindrical and the passages 6*b* extend radially from the wall of the cylindrical cavity. The valve member 8 has a cylindrical peripheral wall cooperating with that of

the cavity and formed with ports which in one limiting angular position of the valve member 8 and rod 7 register with the passage 6*b* to permit fluid flow therethrough, whilst in another limiting angular position of the member 8 the ports in the cylindrical peripheral wall are out of register with passages 6*b* which are closed off by the peripheral wall of the valve member. A base part of the valve member 8 is formed with ports (not shown) to permit fluid to pass between the upper and lower sides of the valve member. The relative dimensions of the passages 6*a*, 6*b* and 6*c* are such that the effective flow cross-section through the piston between chambers 3*a* and 3*b* is substantially less when the valve 8 is in its limiting position closing off the passages 6*b* than when it is in its other limiting position. An actuator (not shown) is provided which cooperates with an eccentric pin projecting from the upper end of rod 7 to effect the rotational movement of the rod 7 necessary to move the valve 8 between the two limiting positions referred to.

The damping capacity of the shock absorber 1, i.e. its effectiveness in absorbing shock energy as the respective vehicle wheel, and the cylinder 2 connected therewith, moves up and down with respect to the piston rod 4 and body 23, can thus be 'switched' between two values by moving the valve 8 from one said limiting position thereof to the other.

Above the cylinder 2 there is provided a main air-spring chamber 9 which surrounds the piston rod 4 and cylinder 2, and is co-axial therewith. An auxiliary air-spring chamber 10 is disposed directly above the main air-spring chamber and also surrounds the piston rod 4 and is disposed co-axially therewith.

The main air-spring chamber 9 is of variable volume and comprises an upper rigid part fixed with respect to piston rod 4 and a lower part in the form of a flexible boot or sleeve fixed sealingly to the upper rigid part and to the upper end of the cylinder 2.

An upper part of the control rod 7 extending from the region of the main air-spring chamber 2 to just short of the upper end of the rod 7 is externally cylindrical and is a sealing rotatable fit in a correspondingly cylindrical bore forming the upper part of the central axial passage through the rod 4. A central longitudinal passage 11 extends axially through this upper part of control rod 7 and although closed at its upper end communicates, adjacent its upper end, via transverse passages in the rod, with an air-supply port in a coupling 15 fitted sealingly around the projecting upper end portion of the rod 7 but rotatable on the rod 7. The two air-spring chambers 9 and 10 can communicate with each other, in one limiting rotational position of the rod 7 relative to the piston rod 4, through the air passage 11 formed in the control rod 7, via communicating passages 12*a* and 12*b* respectively extending radially through the piston rod 4 in the regions thereof respectively adjoining the chambers 9 and 10 and via registering ports 13*a* and 13*b* respectively in the wall of control rod 7.

When the control rod 7 is rotated from the last-mentioned limiting position to another limiting position, the ports 13*a* and 13*b* are moved out of register with the passages 12*a* and 12*b* so that the chambers 9 and 10 are cut off from one another. The piston rod 4 and control rod 7, in combination, and more particularly the parts thereof with ports 13*a* and 13*b* therein therefore function as a control valve or "switch" valve 14 which can connect and disconnect the two air-spring chambers 9 and 10. Opening and closing the switch valve 14 by connecting the disconnecting the two air-spring chambers 9 and 10, varies the effective total air volume in the air-spring and thus varies the spring constant of the suspension.

The control valve 8 makes the cross-sectional area of the communication between chambers 3*a* and 3*b* smaller when the control rod 7 is in its limiting position in which the switch valve 14 is closed and larger when the control rod 7 is in its limiting position in which the switch valve 14 is open.

Vehicle height, herein also referred to as car height, i.e. the mean height of the vehicle body above the road surface as determined by the mean extension of the suspension, is adjusted by varying, in each suspension unit, the air volume in the air-spring chamber 9 or in the two air-spring chambers 9 and 10 if these are in communication. The air passage 11 is connected, via the coupling 15 at the upper end of the rod 7, to a pipe 16. A solenoid valve (not shown) is provided in the pipe 16 and is operable to connect the passage 11 with an air compressor (not shown), or with an exhaust outlet to atmosphere, or to seal off the pipe 16. Car height is adjusted by allowing air to flow into and out of the air-spring chambers 9 and 10 through the air passage 11, depending upon the car height or other conditions detected, through the actuation of the solenoid valve.

Reference numeral 19 designates a coil spring which is disposed around the main air-spring chamber 9 and the respective portions of the piston rod 4 and cylinder 2, with the lower end of spring 19 being suported and located by a spring bearing member 17 fixed to the cylinder 2, and the upper end thereof supported and located by the underside 18 of a rigid housing providing the auxiliary air-spring chamber 10, which housing, to this end, projects radially with respect to the axis of the shock absorber beyond the periphery of the main air-spring chamber 9.

A cover 25 is attached to the body 23 in such a manner as to enclose the upper end of the suspension unit, more particularly to cover the upper side of the bearing 21, mount 24 and the portions of the suspension unit projecting thereabove, including the upper ends of the piston rod 4 and control rod 2, the coupling 15 and the immediately adjoining part of pipe 16. A hole 26 is provided in the cover 25 through which the pipe 16 passes to the above mentioned solenoid valve.

The cover 25 is effective in materially reducing

the transmission to the surroundings of the noise generated around the air passage 11 and coupling 15 due to passage of air through the passage 11 and coupling 15 etc., especially the noise due to air flowing into and out of the air spring chambers when the car height is being adjusted. A greater silencing effect can be attained by lining the inside of the cover 25 with an acoustic absorber (not shown).

The disposition of the main and auxiliary air chambers 9 and 10 around the shock absorber and within the spring 19 surrounding the shock absorber, the provision of the valve 8 controlling the damping capacity of the shock absorber within the piston 5, and the arrangement of the operating rod 7 for that valve and the utilisation of that operating rod, in combination with the piston rod, to form a control valve 14, disposed entirely within the piston rod, for controlling the connection between the main and auxiliary air-spring chambers 9 and 10 are all features conducive to making the entire system in a highly compact unit.

Furthermore, the spring force and damping capacity of the suspension unit can be switched simultaneously by rotation of the control rod 7 and the resulting actuation of the switch valve 14 and the valve 8.

Since the auxiliary air-spring chamber 10 projects radially beyond the periphery of the main air-spring chamber 9, the bottom surface 18 of the auxiliary air-spring chamber 10 serves as the spring bearing to support the upper end of the coil spring 19. This eliminates the need for providing a special spring bearing for supporting the upper end of the coil spring 19, thereby permitting a reduction in the number of parts and the overall size of the system.

Whilst, in the arrangement described above with reference to the drawings, the valve 8 and 14 are arranged to be operated by rotation of the control rod 7 relative to the piston rod 4, it will be appreciated that these valves can be operated, in common, by reciprocation of the rod 7 along its axis, with appropriate modification to the valves 8 and 14.

A vehicle suspension system utilising suspension units as described with reference to the drawing provides the following desirable effects or advantages:

(1) Riding comfort and safety are increased by keeping the vehicle's wheels in firm contact with the road and enhancing steering stability depending upon the acceleration and other factors operating on the vehicle body while keeping the vehicle height at a given level through the variation of the damping capacity of the shock absorber and the spring constant of the air-spring chambers.

(2) The spring constant of each suspension unit can be changed easily since the effective capacity of the respective air-spring can be changed by connecting or disconnecting the two air-spring chambers through the actuation of the respective switch valve.

(3) The auxiliary air-spring chamber and switch valve are compactly incorporated in the suspension system equipped with the main air-spring chamber.

(4) The spring constant of the air spring and the damping capacity of the shock absorber can be changed simultaneously.

(5) With the bottom surface of the auxiliary air-spring chamber serving also as a spring bearing to support the upper end of the coil spring, both the number of parts and the size of the entire system can be reduced.

(6) The propagation of the noise caused by the air supplied to and discharged from the two air-spring chambers for car-height adjustment can be reduced.

CLAIMS

1. A suspension unit for a vehicle including a cylinder, a piston slidable in the cylinder and dividing the space within the cylinder into two chambers, a piston rod extending from the piston axially through one of said chambers and passing sealingly through one end of the cylinder to project therefrom, the suspension unit including a main air-spring chamber of variable volume, and an auxiliary air-spring chamber, disposed around said piston and cylinder at respective axial positions therealong, said piston rod having a longitudinal central passage therein which receives a control rod extending from the piston rod at one end whereby the control rod can be moved relative to the piston rod, said piston rod forming, with said control rod, a control valve which in one position of the control rod relative to the piston rod provides communication between said main and auxiliary air-spring chambers via ports formed through the wall of the piston rod and via said longitudinal central passage, and which control valve, in another position of the control rod relative to the piston rod, cuts off such communication.

2. A suspension unit according to claim 1, wherein said piston provides communication therethrough between said two chambers in the cylinder, and a further control valve is provided operable to vary the effective flow cross-section of the communication between said cylinder chambers, said further control valve being operable by means of said control rod so as to be operated when said control valve controlling the communication between said air-spring chambers is operated.

3. A suspension unit according to claim 2 in which the arrangement is such that operation of the control rod to cut off the communication between the air-spring chambers places said further control valve in a position in which the effective flow cross-section of said communication between the first and second cylinder chambers is relatively small, and operation of the control rod to establish communication between said air-spring chambers places said further control valve in a position in which the effective flow cross-section of said

communication between the first and second cylinder chambers is relatively large.

4. A suspension unit according to any preceding claim, including a coil spring surrounding the piston and cylinder and said main air-spring chamber, said coil spring acting between respective abutments fixed with respect to the piston rod and cylinder, said auxiliary air chamber being formed within a housing which projects radially beyond the main air-spring chamber and forms one of said abutments.

5. A suspension unit according to any preceding claim, wherein said control rod is movable rotationally about the longitudinal axis of the unit to effect operation of said control valve which controls communication between the main and auxiliary air-spring chambers.

6. A suspension unit according to any preceding claim, wherein a passage for the connection of the main air-spring chamber with an air source extends from the main air-spring chamber, through said longitudinal control passage in the piston rod and/or through said control rod, to a coupling port, in the region of said one end of the piston rod, for connection to said air source.

7. A vehicle having a body, wheels and a suspension system incorporating a suspension unit according to any preceding claim extending between the vehicle body and a wheel-supporting member, and means for effecting control movement of the control rod relative to the piston rod.

8. A vehicle according to claim 7 wherein a silencing cover is fitted over the end of the piston rod from which the control rod extends to reduce the propagation of noise from said end of the piston rod.

9. A vehicle according to claim 7 dependent on claim 6 wherein a silencing cover is fitted over the end of the piston rod from which the control rod extends and over said coupling port, to reduce the propagation of noise from said end of the piston rod and a pipe connecting said coupling port with said air source extends through said silencing cover.

10. A vehicle according to claim 8 or claim 9 wherein the inside of said silencing cover is lined with an acoustic absorber.

12. A suspension unit for a vehicle, substantially as hereinbefore described with reference to, and as shown in, the accompanying drawing.

13. A vehicle incorporating a suspension unit according to claim 1, and substantially as hereinbefore described with reference to, and as shown in, the accompanying drawing.

14. Any novel feature or combination of features described herein.

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